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Abstract

CRITICAL FLOW PHENOMENA IN TWO-PHASE MIXTURES AND THEIR RELATIONSHIPS TO REACTOR SAFETY

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The expulsion of the coolant from pipe and vessel breaks in high pressure water systems will involve metastable and two-phase flow phenomena including critical or choking flows. Containment and emergency cooling systems must be designed to cope with the transient and maximum pressure buildups and with the rate of coolant loss.

Flow rates calculated for the coolant expulsion with no liquid vaporizing are significantly greater than the rates calculated for two-phase homogeneous flow. Thus a variety of analytical models has evolved to predict critical, two-phase flow through apertures including orifices, nozzles, and pipes. It is recognized, too, that the nature and positioning of the break will influence the type of coolant outflow and consequently the choice of the model. Critical flow rates predicted by the various models are presented for coolants such as water, cryogenic fluids, and liquid metals.

The literature on two-phase flow phenomena constitutes an important aspect of the understanding needed in evaluating the problems involved; however, only

relatively recent experiments provide the insight needed for the evaluation of practical cases. Available experimental results for critical two-phase flow in pipes are presented and compared to the predictions of the analytical models. The discussion includes the judgments for the merits and applicability of the models. Coolant expulsion (blowdown) tests have been carried out to establish design criteria for the prediction of the two-phase flows, and these results are also discussed and compared with the predictions.

In presenting the current status of the nuclear reactor safety programs, coolant discharge studies now in progress in the United States are briefly described. Preliminary results include investigations of the state of the fluid within the vessel (pressure and void measurements), pressure distributions in the aperture and pipe sections, variations of the L/D ratios for the discharge sections, and measurements of the voids at the critical discharge position. Nearly all tests in progress involve water as the fluid with system pressures extending up to 2000 psig. The further implementation of the testing programs with the use of cryogenic fluids provides information on the two-phase critical flow phenomena as related to nuclear space applications. The use of freon provides both visual and quantitative results.

For any given set of conditions describing a loss of coolant accident, unresolved problems still remaining for predicting the discharge rates are noted, with some estimation of the bounds for the errors. A program designed to demonstrate the integrated effects of a loss of coolant accident is described.